Depth Discrimination and Range Estimation of Multiple Sources in Shallow Waters

I-Tai Lu
Polytechnic Univ.
Route 110
Farmingdale, NY 11735
phone: (516) 755-4226 fax: (516) 755-4404 email: itailu@rama.poly.edu
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LONG-TERM GOAL

To develop wave-oriented phase coherent signal processing algorithms (which address and incorporate the physics of acoustic wavefield propagation through and scattering from an inhomogeneous, noisy, time varying, and stochastic ocean environment) to characterize targets and the environment for applications in both passive and active systems.

OBJECTIVES

To validate a new and practical system concept and to develop new wave-oriented phase coherent inversion algorithms for classifying and localizing multiple sources in noisy and time-varying shallow waters without knowing the sound speed profiles. The approaches should be able to adapt (self-optimize) in the face of changing environmental and system conditions.

APPROACH

There have been many efforts to develop inverse source algorithms such as matched-field, matched-traveltime, matched-ray, and matched-mode approaches. However, none of the existing methods can work well in real time under simultaneous excitations of several sources. Furthermore, all of these algorithms operate properly only when accurate descriptions of the environments are available. Since the environment is time-varying and full of noises created by surface ships and other sources, it is impractical to implement any real time monitoring system using these methods. A real time monitoring system with two mutually perpendicular horizontal arrays (which can be bottom mounted) is proposed for *range estimation, depth discrimination, and spectrum estimation* of multiple sources where the SSP of the environment is not required. The key ideas are, first, to use sufficient long arrays for deriving modal wave numbers and composite modal amplitudes excited by multiple sources in multiple frequencies and, then, to utilize a sufficient large number of frequency samples for obtaining unknown source ranges and modal amplitudes for every source and every guided mode.

WORK COMPLETED

The proposed system is tested numerically in an simplified shallow water model. The conventional spectral estimation model is extended to incorporate the array coordinate dependence for wavenumber inversion and to account for the frequency dependence for range estimation. A new Singular Value Decomposition -Eigenmatrix Pencil method is employed to find the complex modal wavenumber and the complex source ranges. This high-resolution algorithm is proven to be most successful for the

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current application. A new 2-dimensional MUSIC algorithm for estimating angles and traveltimes of multiple arrivals is tested successfully.

RESULTS

In numerical simulations, the power spectrum and the range for each source are approximately derived from its fundamental modal phase and amplitude, respectively. Furthermore, depth discrimination is achieved by examining the excitation strength of the fundamental mode especially when the environment has a downward refracting SSP. If the SSP or the modal eigenfunctions is approximately known, more accurate source depths can be derived from modal excitation strengths by a matched-mode procedure. A new 2-dimensional MUSIC algorithm has been employed to estimate simultaneously the angles and the traveltimes of multiple arrivals. Using this method, the number of antennas does not have to be larger than the number of arrivals. The resolution is therefore not restricted by the aperture size of the antenna array.

IMPACT/APPLICATION

Source localization technologies are of vital importance to the US Navy. The success of the preliminary results of the proposed research program is a fundamental breakthrough in inverse source algorithms. These results will enable the US Navy to develop inexpensive real time systems to monitor broad regions in crucial and busy shallow waters so as to detect underwater vessels, estimate their ranges and acoustic power spectra, and discriminate them from surface ships. These results may also be employed for tracking whales or for other civilian applications. The two-dimensional spectral estimation method enhance the system resolution greatly.

PUBLICATIONS

A. JOURNAL PAPERS

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7. I-Tai Lu and H. S. Wu, " Range estimation and depth discrimination of multiple sources in noisy shallow waters without knowing sound speed profiles," submitted to J. Acoust. Soc. Am.
8. I. T. Lu and T. C. Yang, "Alternative Representations of Acoustics Field Scattered by Submerged Targets in Ocean Waveguides" in preparation for J. Acousc. Soc. Am.

B. CONFERENCE PAPERS

1. I-Tai Lu and Hsuan-Ling Wu, "Range Estimation of Multiple Sources in Shallow Waters Without Knowing the Sound Speed Profile," Third International Conference on Theoretical & Computational Acoustics, Columbia Univ., New York, July 14-18, 1997.
2. I-Tai Lu and Fu-Po Wu, "A High-Resolution Spectral Estimation Approach for Evaluating the Traveltimes and Resonances of Scattering Returns from Submerged Targets," Third International Conference on Theoretical & Computational Acoustics, Columbia Univ., New York, July 14-18, 1997.
3. I-Tai Lu and T. C. Yang, "Alternative Representations of Acoustics Field Scattered by Submerged Targets in Ocean Waveguides," Third International Conference on Theoretical & Computational Acoustics, Columbia Univ., New York, July 14-18, 1997.

C. INVITED TALKS

1. Naval Research Laboratory, Acoustics Division, Washington D.C., Dec.1, 1998.
2. National Taiwan University, Taipei, Taiwan, Dec. 21, 1998.
3. National Tching Hwa University, Hsin-Chu, Taiwan, Dec. 22, 1998.
4. National Central University, Chung-Li, Taiwan, Dec. 23, 1998.
5. National Chiao Tung University, Hsin-Chu, Taiwan, Dec. 24, 1998.